Comparative Analysis of Canine Cardiac Structure Variations of Different Breeds and Genders Using Echocardiography Views

Caleb M. Boren

Grade 12

Roscoe Collegiate ISD

700 Elm Street Roscoe, Texas 79545

Animal Systems

Division 5

Table of Contents

ABSTRACT

The objective of this research project was to determine if canine gender and breed have a significant impact on the variations of internal cardiac structure measurements obtained during two-dimensional and motion-view echocardiography. External body measurements were taken, as well as internal cardiac structure measurements taken from four different echocardiographic views. These external body measurements included the following: thoracic cavity circumference (TCC), the width of shoulders (WS), length of thoracic spine (LTS), and the left front leg length (LFLL). A ultrasound machine was used to collect the internal structure measurements. The two modes on the ultrasound that were used included two-dimensional and motion-view echocardiographic settings. The internal measurements that were collected included the following: left and right ventricular areas, left and right atrial areas, left and right ventricular and atrial wall thicknesses, and the interventricular and interatrial thicknesses. The data showed that more active male canines had larger internal cardiac structures compared to female canines. The cardiac structures that had the most observed variance included the left ventricle, left atrium, left ventricular posterior free wall, the interventricular and interatrial septums, and the aorta. The data collected from this experiment proved the hypothesis correct.

Keywords: two-dimensional, motion-view, echocardiography, internal structures, external structures.

INTRODUCTION

Canines vary not only in physical appearance but also physiological characteristics, especially when it comes to gender. By knowing the differences between male and female cardiac structure sizes among different sizes of dogs, veterinarians in private practice will be able to more accurately diagnose cardiac diseases and the severity of the condition. The cardiac structures among different sizes and breeds of dogs are very similar with slight variations to the size and shape of those structures.

The integration of echocardiography into veterinary practices across the country has allowed veterinarians a new means of diagnosing cardiac abnormalities. Echocardiography gives veterinarians the opportunity to assess not only the overall morphology of the heart, but also the function; including pumping capacity, and the pattern of blood flow in real time (Singh P. et al., 2014). The interpretation of echocardiograms relies on both a qualitative and quantitative assessment of cardiac structures as seen in two-dimensional and motion-view evaluation (Hall et al., 2008). Logically, sources of observed variation may arise from operator techniques, as well as exact quantitative differences between normal animals that may be affected by age, genetics, breed, body size, level of training physiological hypertrophy, or determinants of cardiac performance such as: heart rate, preload, afterload, contractility, and atrial or ventricular chamber synergy (Hall et al., 2008).

The heart is a muscular organ composed of cardiac muscle which contracts to transport nutrient and oxygen-rich blood throughout the body. The heart contains a left and right atrium, which receives blood returning from both the systemic and pulmonary circuits (Marieb & Hoehn, 2016). The left and right ventricles of the heart work as the two pumping chambers which move blood throughout the cardiovascular system. The heart can be divided into two different sections, the right side and the left side. The right side of the heart contains the right atrium and ventricle, which is separated by the tricuspid valve. The left side of the heart includes the left atrium and ventricle, which is divided by the bicuspid (mitral) valve. An interventricular septum separates the ventricles, while an interatrial septum separates the atria. The heart walls are composed of three layers: the epicardium, the myocardium, and the endocardium. A fibrous sac known as the pericardium encapsulates the heart which protects it and anchors it to the chest wall (Marieb & Hoehn, 2016).

Despite the copious amounts of data existing comparing the different sizes of various cardiac structures among breeds, there is significantly less published research investigating the structure size based on the gender of the animal. If canine gender is related to the size of cardiac structures; then, more active male canine breeds should have larger internal cardiac structures than females. This newly collected information could prove to be very beneficial to veterinarians who have limited experience in canine echocardiography, and owners who are interested in advancing their knowledge about what is studied during an echocardiogram. Not many veterinarians, particularly rural veterinarians, are board-certified in the specialty of small animal cardiology. By increasing their knowledge of small animal cardiology, they can better serve the communities that they practice in. There is a very small chance that rural veterinarians have much experience in the field of cardiology, or have connections with other veterinarians that are board-certified. By knowing the impacts of gender and breed on the normal structure parameters, veterinarians can more accurately diagnose cardiac diseases and abnormalities. Therefore, it is imperative to investigate the variations of internal cardiac structure and size that may be found during echocardiography among different genders of canine breeds.

LITERATURE REVIEW

The Echocardiography in the Cardiovascular Laboratory: A Guide to Research with Animals:

The heart of quadruped mammals presents with the heart located in the middle part of the chest, with the apex pointed to the left; also, the chest is generally keel-shaped, allowing to obtain images from both left and right sides of the thorax. Echocardiography allows for more accurate morphological and hemodynamic investigation of the heart. Having knowledge of quadruped mammals and their anatomy, as well as how to properly operate the technology is essential. The frequency of the transducers must be adjusted according to the body mass of the animal to obtain clear images of internal cardiac structures. The frequency of the transducer is inversely proportional to the ultrasound beam penetration, the smaller the mammal the greater frequency needed for the probe. To obtain optimal images, the animal's chest hair should be removed to prevent the presence of air between the transducer and the body surface. For canine positioning, it is indicated that the best position is left lateral recumbency with limbs being extended cranially and caudally to maximize the chest window. (Abduch, 2013)

Practical Echocardiography: ECHOES in the "REAL WORLD":

As the implementation of echocardiography in private veterinary practice continues to grow, many veterinarians are concerned if echocardiograms can be obtained and used to accurately diagnose cardiac disease without the use of Doppler. Despite many veterinarians not being capable of using Doppler echocardiography, grey-scale two-dimensional and motion-view echocardiography can still be used to diagnose cardiac disease. Two-dimensional grayscale echocardiography allows for the ultrasonographer to evaluate cardiac chamber size, wall thickness and motion, valve conformation and motion, and pericardial and pleural fluid. When performing an echocardiogram, it is critical that an acoustic window is shaved into the chest. Ultrasound gel should be applied to the canine once the animal is positioned in lateral recumbency with the down leg being extended cranially. If images are difficult to obtain, adjust the angle of the transducer to somewhere between fifty and seventy degrees to improve the overall resolution. The apex beat will be under the sternum; this beat will be used to help obtain different views of the heart. (Beard, n.d.)

Guidelines for the Echocardiographic Studies of Suspected Subaortic and Pulmonic Stenosis:

Knowledge of cardiac anatomy is essential in making the correct pathoanatomical diagnosis of blood flow abnormalities. The left ventricular outflow tract, in its long axis view, can be represented as a truncated cone laid down on its side, with the larger base in the ventricle with smaller top at the top of the aortic valve leaflets. In a short axis view, the contributing structures depend on the level of the cross section. (Bussadori et al., 2000)

Echocardiographic Parameters and Indices in the Normal Beagle Dog:

The use of ultrasonography in veterinary practices has been on the rise for many years because of its usefulness. Ultrasonography is able to distinguish body fluids from soft tissues, as well as show the spatial relationships between structures and moving organs. The use of ultrasonography proves to be effective in pharmacological and toxicological research on the cardiovascular system. The main purpose of the research study was to establish echocardiographic parameters for beagles, and to further investigate the correlations between body weight and structure sizes. (Crippa, 1992)

Echocardiography in General Practice: 4 Views to Master:

A common mistake of those new to performing and interpreting echocardiography is the creation of mass lesions by angular transections (incorrect positioning of the ultrasound beam) of normal cardiac structures. The initial focus should be on chamber structure and dimension, systolic function, and presence or absence of any effusions (pleural or pericardial) or masses. If sedation is used, understanding the effects of various drugs on heart rate, chamber size, and cardiac function is essential. The right parasternal acoustic window is located between the right 3rd and 6th intercostal spaces (usually 4th or 5th) and between the sternum and costochondral junctions. It is typically found near the strongest palpable right apical beat. (Estrada, 2107)

Introduction to Echocardiography in Small Animal Practice:

Two-dimensional visualization of the heart provides information about its shape, size and spatial relationships of the structures during the cardiac cycle. Motion-view echocardiography uses ultrasonic pulses from crystals to create a pencil beam of sounds that can be pointed towards different structures to study them individually. Motion-view echocardiography does not show an image of the heart, but a line that indicates the positions the heart is in throughout the cardiac cycle. Echocardiography is used to evaluate cardiac chamber size, wall thickness, wall motion, valve configuration and motion. Also, the proximal great vessels (aorta and pulmonary artery) are able to be seen as well. Most examinations can be completed with minimal to no chemical restraint. A major limitation of echocardiography is the quality of the images that can be obtained sometimes. A number of factors such as rapid changes in intrathoracic pressure, chest wall thickness, and movement can all distort the images and cause artifacts to be seen. Air-filled structures such as the lungs and bones reflect ultrasound beams causing distortion. The intercostal spaces of the axillary region at the level of the heart are the best places for echocardiographic images to be obtained. A common artifact that can be mistaken for an anomaly is called “drop-out.” This occurs at the level of the fossa ovale. To confirm or rule-out the presence of cardiac defects, images from multiple views should be collected. (Ferasin, 2014)

<u>Reference Values of M-Mode Echocardiographic Parameters and Indices in Conscious Labrador Retrievers</u>:

Measurements of cardiac dimensions and the analysis of cardiac functional parameters are essential to diagnose pathological conditions. Making sure these are accurate can determine if an animal is suffering a cardiac disease. Echocardiography allows for an analysis of the spatial relationships between organ structures. Echocardiographic indices show significant breed variations and how it relates to other breeds. Research study participants were examined for Dirofilaria immitis because of the potential for severe cardiac tissue damage. It was also determined that the body weight has a major impact on echocardiographic values. (Gugjoo, 2014)

<u>Meta-analysis of Normal Canine Echocardiographic Dimensional Data Using Ratio Indices</u>:

The evaluation of echocardiographic images relies heavily on both qualitative and quantitative analyses by two-dimensional and motion-mode echocardiography. Variations can arise from things such as operator technique, and artifacts in the images. The goal of this study was to investigate the dependence of echocardiographic ratio indices on age, body weight and breed. It was found that having canines in the study that were a mix of different breeds, did not have a major impact on the findings of the study. The study suggests that age affects the overall cardiac function. As canines age, the shape of the heart continues to change. In older canines, calcifications were occasionally noted in the echocardiographic images obtained and were found to not have a major impact on the overall structure or function of the heart. (Hall et al., 2008)

<u>Checklist of Cardiac Ultrasound Images to Obtain</u>:

The four chamber right parasternal long axis is obtained from the right side of the patient, and displays the relative proportions of all four chambers. The interventricular and interatrial septum, and the bicuspid valve morphology is easily obtained from this position. The four-chamber parasternal short axis is obtained from the right side. This view is used to evaluate left ventricular posterior wall thickness, as well as mitral valve morphology. (IDEXX Laboratories, 2011)

<u>Human Anatomy and Physiology</u>:

The heart is a muscular organ composed of cardiac muscle. There are three layers of muscle found in the heart: the epicardium, myocardium, and endocardium. The heart is a pump that transports blood through the pulmonary and systemic circuits. The heart is divided into the left and right sides by the interventricular and interatrial septums. The two stages of the cardiac cycle are diastole and systole. Diastole occurs when the heart is open and fills with blood; systole occurs when the heart contracts and ejects the blood out through the body. (Marieb, 2016)

Evaluation of Four 2 Dimensional Echocardiographic Methods of Assessing Left Atrial Size in Dogs:

Echocardiography is a standard noninvasive assessment of cardiac anatomy, function, and pathology. Evaluation of the cardiac chambers includes measuring the dimensions and comparing them using a ratio. Four different methods of assessing left atrial size were included in this research study. Cardiac chamber size is directly related to canine body weight. (Rishniw, 2000)

Echocardiography as an approach for canine cardiac disease diagnosis:

Echocardiography provides useful information regarding the structure and function of the heart. It gives the ultrasonographer a view of the internal cardiac structures, as well as the valves that separate the ventricles and atria. In addition to the great views of cardiac structures that echocardiograms provide, they are also able to show movement of blood on its journey through the different chambers and vessels of the heart. The aim of this study was to use echocardiography in conjunction with other diagnostic procedures to determine the effectiveness of echocardiography. The measurements collected during this study included: left ventricular internal dimensions at end-systole and end-diastole, left ventricular posterior wall thickness at end-systole and at end-diastole, interventricular septal thickness at end-systole and at end-diastole, aortic root dimension at end-diastole, left atrial dimensions during ventricular systole. The measurements were collected using two-dimensional echocardiography and motion-view echocardiography. This study confirmed the effectiveness of using echocardiography to diagnose conditions such as dilated cardiomyopathy (DCM), and pericardial effusion (PE). (Singh et al., 2014)

MATERIALS & METHODS

A survey created in Google Forms was sent out to all teachers of Roscoe Collegiate ISD. This survey was used to collect data about owner's canines and to see if they were interested in participating in a noninvasive cardiac study to evaluate their cardiac structures. The survey asked questions relating to the following: age, breed, gender, intactness of reproductive systems, shaving, and transportation. From the survey, a list of people was selected to participate in the cardiac study. A second survey was sent out to only the people selected from the first survey. The second survey asked questions in relation to the following information: age, housing options, rabies vaccination status, and the best days for the owner to drop off their pet.

The actual research experiment was conducted in the dog ward of the Edu-Vet Pet Hospital located in Roscoe, Texas. In the dog ward, two portable tables, with wheels, were set up one foot apart with a piece of two by two wood set on top of these tables, near the edge. This piece of two by two wood had a pre-cut elongated groove carved out of the side, which allowed for the ultra-sonographer easy access to the left lateral side of the patient's chest. Two chairs were placed opposite of each other on the two outer sides of the portable tables to allow for veterinary staff to sit comfortably while restraining the patients in left lateral recumbency. Three padded, white towels were used to cover the piece of two by two wood and tables to allow for maximum protection from wood splinters, comfort during the procedure, and easy clean-up between patients. Along with the towels, three thick fabric pads were placed on top of the piece of wood and table, without covering the cut-out groove, to allow for comfort.

The ultrasound machine was placed against the wall near the tables to allow easy access to the patient's chest wall. The ultrasound machine was plugged into the wall to ensure that the ultrasound machine did not power off in the middle of an exam. The small animal cardiac ultrasound probe was removed from its protective case and attached to the portable ultrasound machine. One veterinary assistant entered in the patient and client information into a new exam while two other veterinary assistants used hair clippers to shave a portion of the chest hair to create a window for the ultrasound probe. The patient's elbow was pulled back against the side of the chest to give the veterinary assistants a general idea of where to create the window at. Once this spot was located, a veterinary assistant shaved three to four inches farther than that point of the elbow and on both sides of the chest to provide enough space for the ultrasound probe to scan the chest. This shaved area went from the left to right lateral sides of the chest.

Once the patient was transported from the treatment area of the hospital to the dog ward, two veterinary assistants lifted the patient and placed them on the exam table. Once the patient was restrained by two veterinary assistants in left lateral recumbency, a generous amount of ultrasound gel was applied onto the shaved window of the chest and left there to sit for two minutes. During these two minutes, the ultrasound technician used two fingers to palpate the patient's chest just below the xiphoid process to search for the apical beat of the heart. This apical beat allowed for the ultrasonographer to have a general area of the patient's heart and to get the best images possible. After two minutes, the ultrasound technician retrieved the small animal cardiac ultrasound probe, that came with the ultrasound machine and proceeded to find an image of the heart. For this experiment, an echocardiographic examination protocol was created with the help of Dr. Betsy Oesch, and articles from veterinary journals. This protocol was put in place to ensure that all patients were examined the exact same way to minimize variations in the data collected.

The first image in need of collection, was a view from the four-chambered right-sided parasternal long axis view. This view was obtained by using the small animal cardiac probe to scan the area between the right third and sixth intercostal rib spaces between the sternum and costochondral junctions (Estrada, 2017). This area is the general location where the right apical beat is the strongest. From a four-chambered right-sided parasternal long axis view, the following structures are visible: chordae tendineae, left atrium, left ventricle, left ventricular free wall, mitral valve, papillary muscle, right atrium, right ventricle, and the tricuspid valve (Estrada, 2017).

Next, a five-chamber right-sided parasternal long axis view was obtained. To move from a four-chambered right-sided parasternal long axis view to a five-chamber right-sided parasternal long axis view, the small animal cardiac ultrasound probe was rotated about ninety degrees and tilted slightly cranially. From a five-chambered right-sided parasternal long axis view, the following structures are visible: proximal ascending aorta, left atrium, left coronary artery, left ventricle, right atrium, right pulmonary artery, and right ventricle (Estrada, 2017).

Thirdly, a four-chambered right-sided short-axis view was collected. This view gives the ultrasonographer a view of the left ventricle the level of the papillary muscles. To obtain this view, the plane of the ultrasound beam is oriented perpendicular to the long axis of the heart, with the transducer index mark pointing cranioventrally. From the four-chamber position, the transducer is rotated about ninety degrees counterclockwise. Proper orientation is confirmed with various landmarks of cardiac structures and circular symmetry of the left-sided ventricle. Several short-axis images can be obtained at various levels by fanning the transducer from the apex to the base (Estrada, 2017). From the four-chambered right-sided short-axis view the following structures are visible: anterior papillary muscles, left ventricle, posterior papillary muscle, and right ventricle (Estrada, 2017).

Finally, a right-sided short-axis view at the level of the left atrium and aorta was obtained. This view was obtained by starting at a four-chambered right-sided short-axis view and fanning the transducer up from the base of the heart towards the left atrium and aorta. From the right-sided short-axis view at the level of the left atrium and aorta view the following structures are visible: left atrium, left coronary cusp, non-coronary cusp, pulmonic valve, right coronary cusp, right ventricle, and tricuspid valve. From all four of these views, images using both two-dimensional and motion-view echocardiography were used. Two-dimensional echocardiography was used to view the cardiac structures when the heart was in diastole. Motion-view echocardiography was very useful to see when specific structures entered diastole. Motion-mode echocardiography is used when the cardiac cycle of a specific internal cardiac structure is needed (Ferasin, 2014). Instead of viewing every structure in one image, a single structure can be singled out to be more carefully analyzed. This method of examination was preferred when determining if a certain cardiac structure was functioning in optimal condition.

After the procedure, had been completed, the patients had the remaining ultrasound gel wiped off of their chest. Dry paper towels, as well as wet wipes were used to completely remove all traces of the ultrasound gel. In cases were the ultrasound gel had dried, rubbing alcohol was used to remove the dried on residue. The canine was made comfortable either in their carrier, or in a cage in the treatment area. They were left alone until their owners arrived to pick them up later in the day. While the patients were resting, Dr. Betsy Oesch assisted in measuring the structures using the built-in features of the ultrasound machine. Multiple measurements were taken from each view so that they could be averaged to receive a more accurate measurement.

Every measurement was measured using cm. Once the values were collected and checked for accuracy, they were entered into the log book. Each entry in the logbook was verified by another person to ensure the values were accurate. It was hypothesized if canine gender is related to the size of cardiac structures; then, more active male canine breeds should have larger internal cardiac structures.

RESULTS

According to the data, the structures that had the most variance seem to be the left ventricle, left ventricular posterior free wall, the interventricular and interatrial septums, and the aorta. Below, the graphs were critically analyzed and explained. Some chart variations and abnormalities were noted in the figure descriptions, as well as discussed further in the Discussion and Conclusion section of this paper.

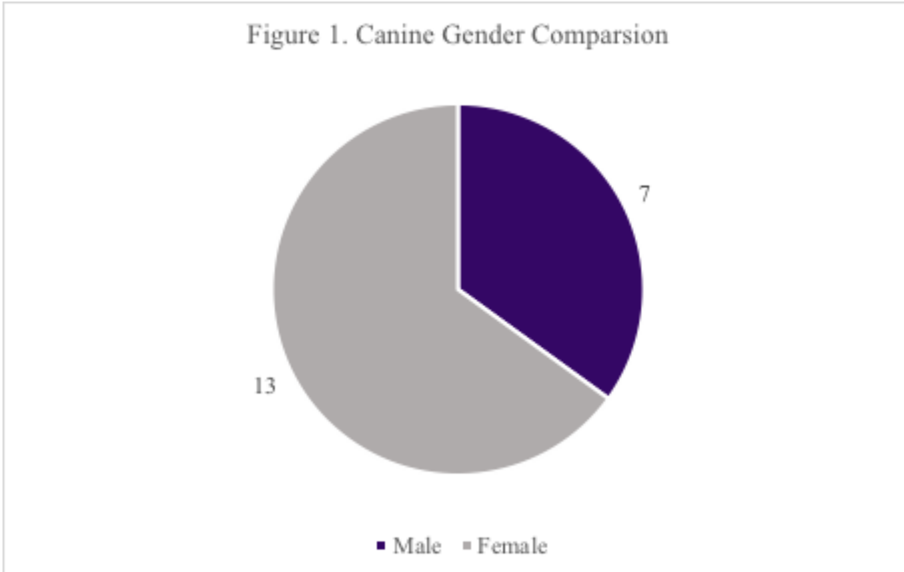

Figure 1. In this figure, a pie chart is used to display the ratio of female patient to male patients. As seen above, there were a total of 20 patients involved in this cardiac study. Out of these 20 patients, there were 13 female patients, and seven male patients.

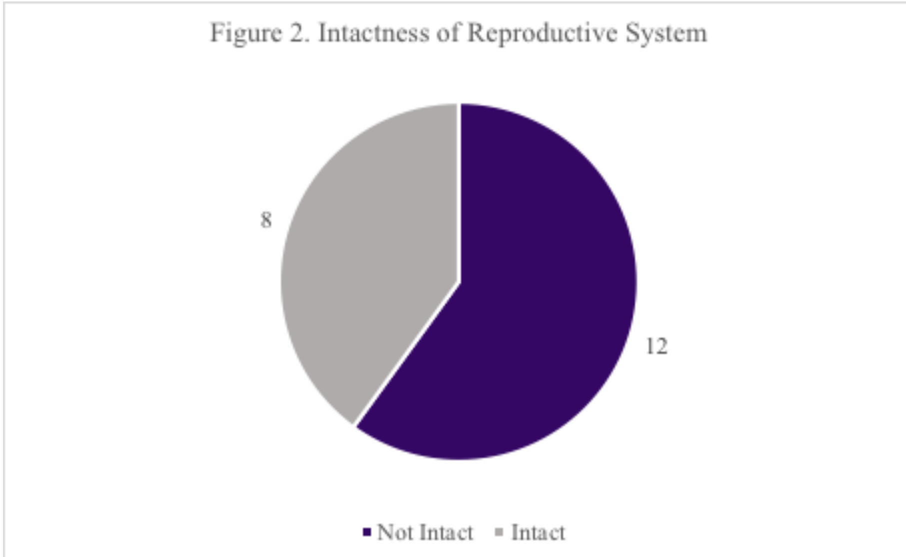

Figure 2. In this figure, a pie chart is used to display the percentage of intact compared to not intact male and female reproductive systems. As seen in the chart above, 12 out of 20 patient's reproductive systems were not intact, while eight out of 20 patient's reproductieve systems were intact.

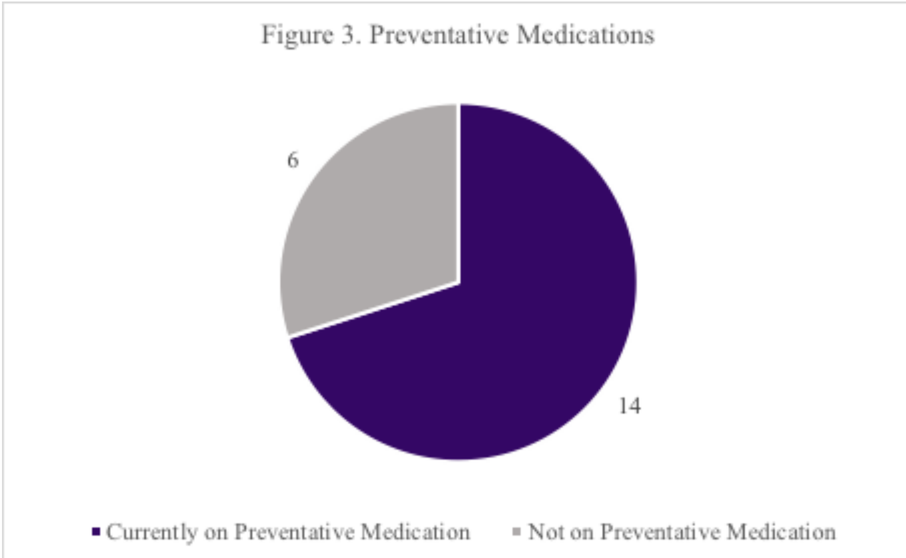

Figure 3. In this figure, a pie chart is used to display the ratio of patients that were on preventative medications such as Heartgard™, Tri-Heart Plus™, Simparica™, Frontline™, and Bravecto™. As seen above, there were 14 out of 20 patients that were on preventative medications at the time of the study. The remaining 6 out of 20 patients were not on any form of preventative medication. This information was important because some medications, especially that have a direct effect on the heart, can directly increase or decrease the size of certain internal cardiac structures.

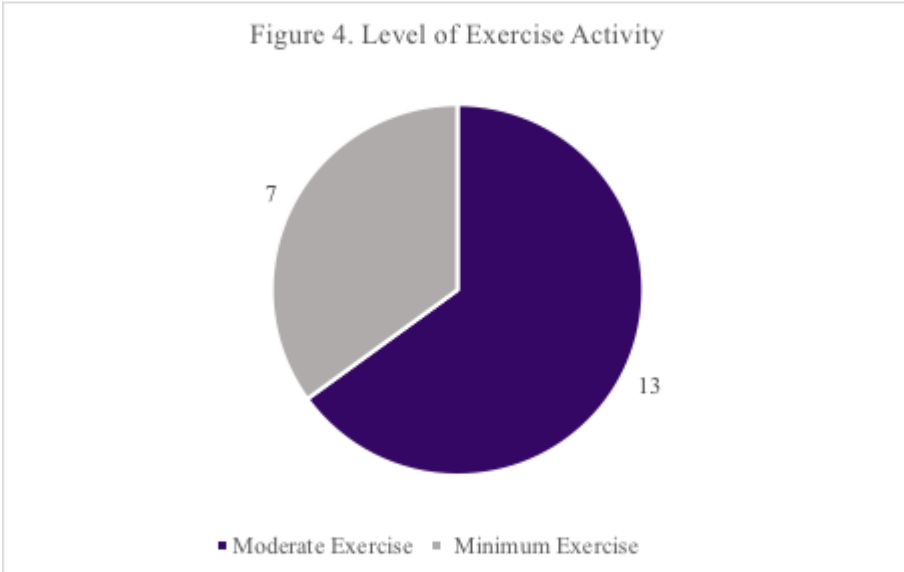

Figure 4. In this figure, a pie chart is used to display the level of exercise that the owners subject the patients to. The patients were placed into a category based on their level of exercise. There were seven out of 20 patients placed into the slight exercise category. The moderate exercise category included 13 out of 20 patients. This information was relevant to the study because more athletic canine breeds and canines subject to higher levels of activity have a more muscular heart.

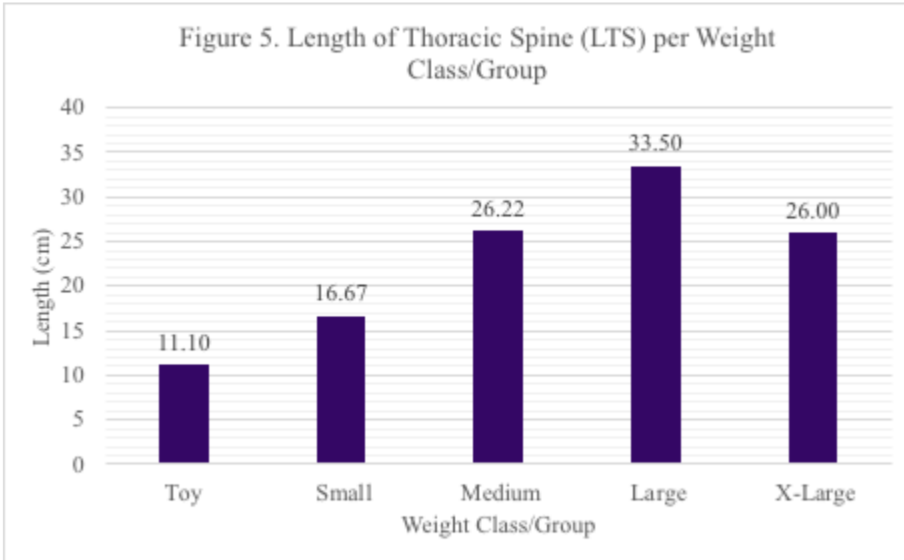

Figure 5. In this figure, a clustered column chart is used to display the average length of the thoracic spine (LTS) for each weight/class group. This is relevant to the study because it has been discovered through other studies that heart size is proportional to the length of the thoracic spine.

Figure 6. In this figure, a clustered column chart is used to display the average width of shoulders (WS) for each weight/class group. This is relevant to the study because it has been discovered through other studies that heart size is proportional to the width of a canine's shoulders.

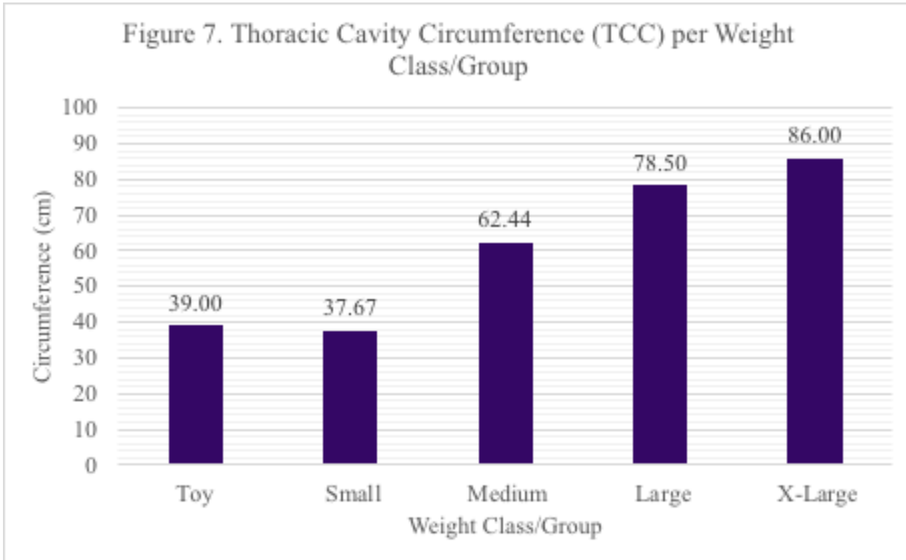

Figure 7. In this figure, a clustered column chart is used to display the average thoracic cavity circumference (TCC) for each weight/class group. This is relevant to the study because it has been discovered through other studies that heart size is proportional to the thoracic cavity circumference of a canine.

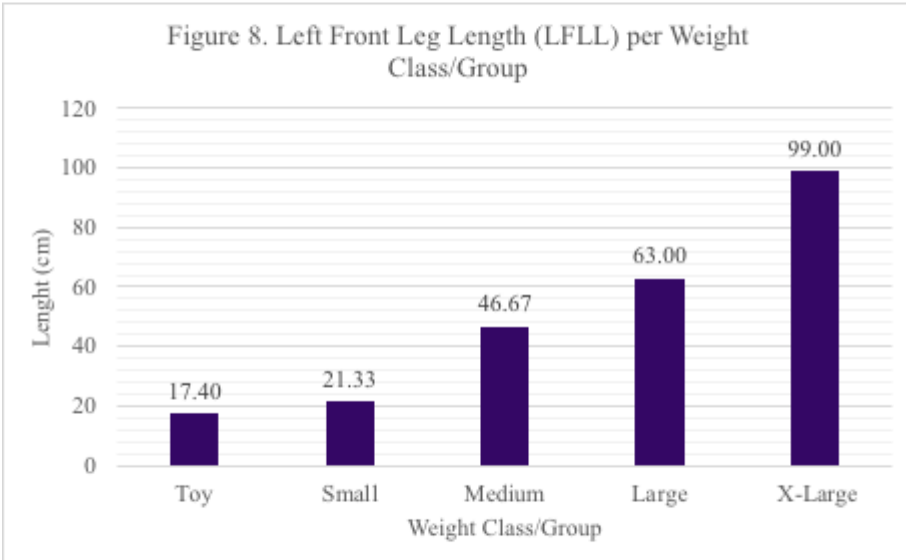

Figure 8. In this figure, a clustered column chart is used to display the average left front leg length (LFLL) for each weight/class group. This is relevant to the study because it has been discovered through other studies that heart size is proportional to the length of a canine's front legs.

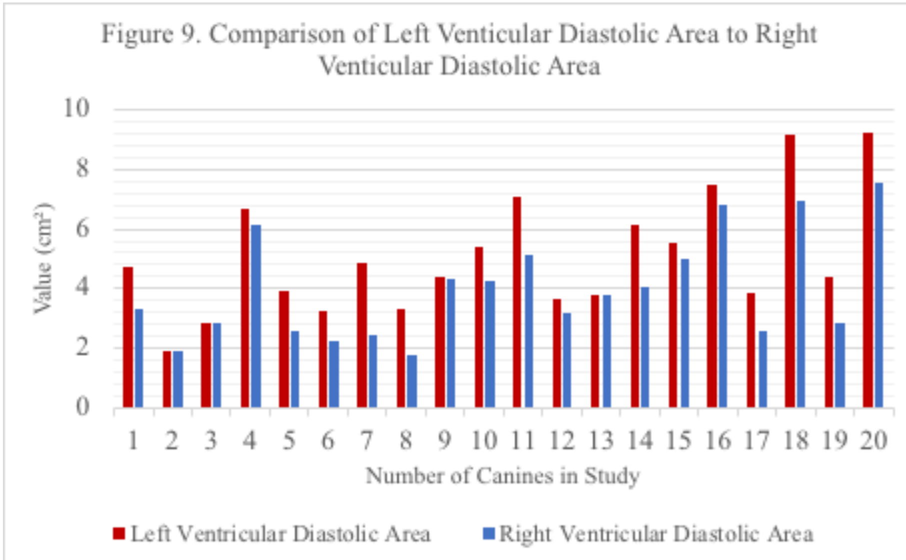

Figure 9. In this figure, a clustered column chart is used to display and compare the left and right ventricular diastolic area for all twenty patients involved in the cardiac study. As expected, the left ventricle had a greater area than the right ventricle in all patients. Some of the measurements between ventricles were very close, most likely due to significant variations in age, as well as disease.

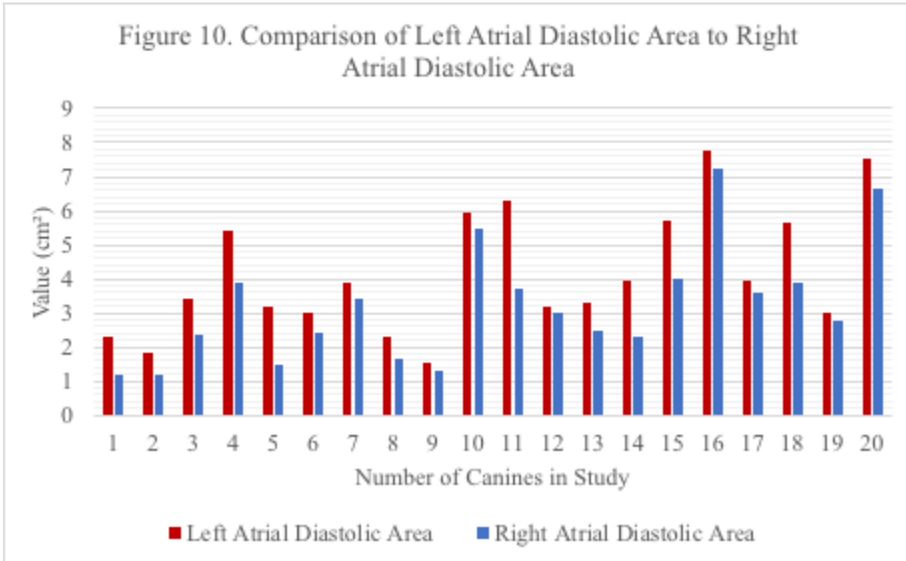

Figure 10. In this figure, a clustered column chart is used to display and compare the left and right atrial area for all twenty patients involved in the cardiac study. As expected, the left atrium had a greater area that the right atrium in all patients. Some of the measurements between atriums were very close, most likely due to significant variations in age, as well as the disease.

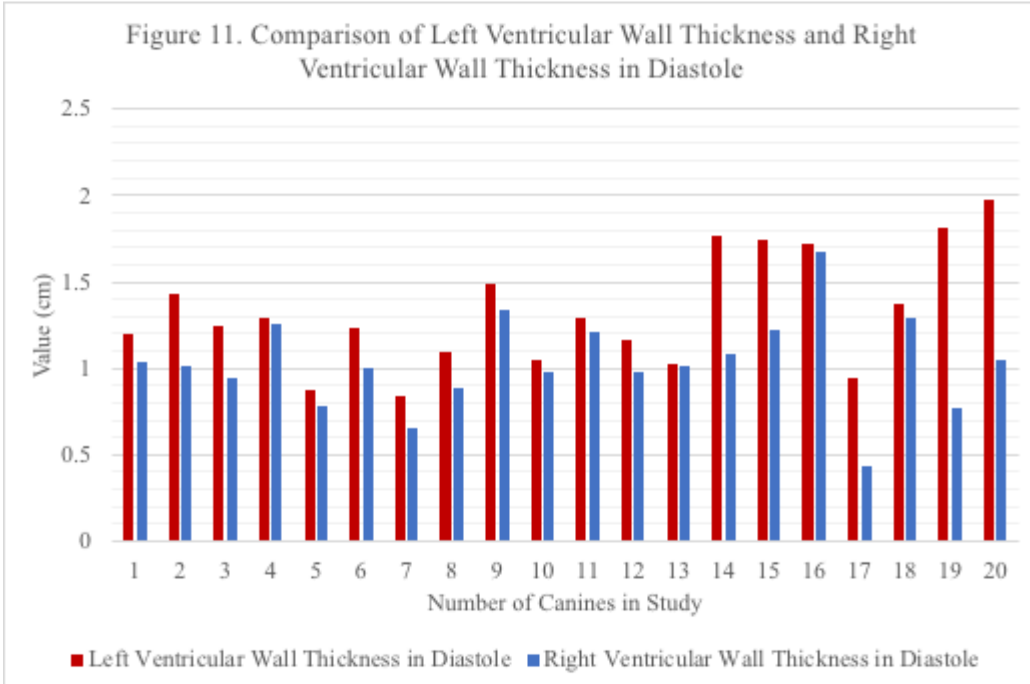

Figure 11. In this figure, a clustered column chart is used to display and compare the left and right ventricular wall thickness for all 20 patients involved in the cardiac study. As expected, the left ventricle wall had a greater thickness than the right ventricle in all patients. Some of the measurements between ventricular walls were very close, most likely due to significant variations in age, as well as disease.

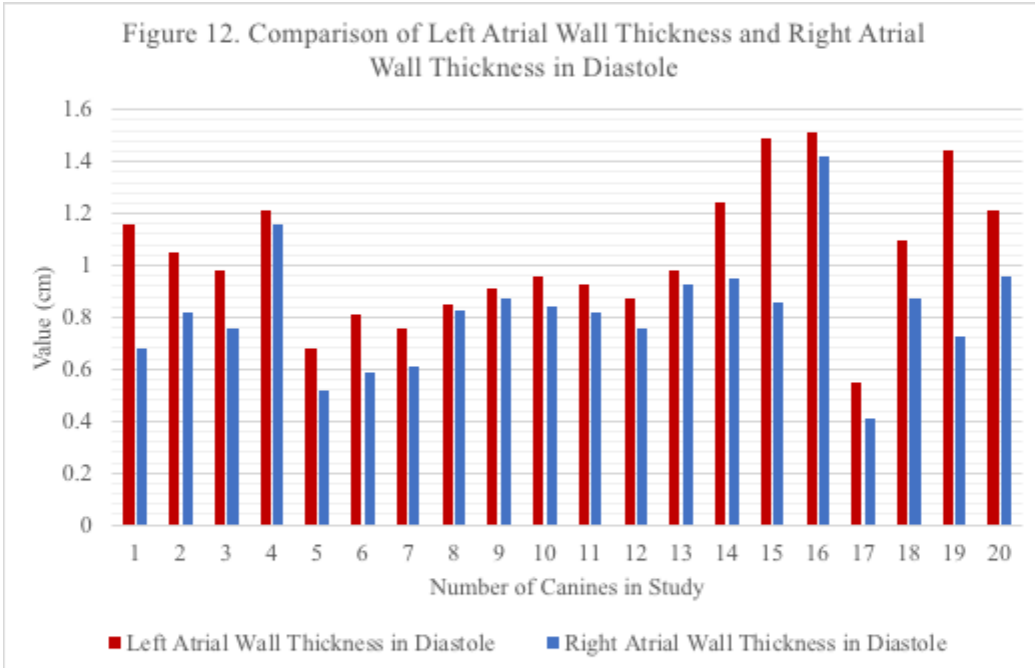

Figure 12. In this figure, a clustered column chart is used to display and compare the left and right atrial wall thickness for all 20 patients involved in the cardiac study. As expected, the left atrial wall had a greater thickness that the right ventricle in all patients. Some of the measurements between atrial walls were very close, most likely due to significant variations in age, as well as disease.

Figure 13. Animal Weight Class/Group Key

Weight Class/Group	Pounds (lbs)	Kilograms (kg)
Toy	**0 - 12**	**0 - 5.44**
Small	**13 - 25**	**5.90 - 11.34**
Medium	**26 - 50**	**11.79 - 22.68**
Large	**51 - 99**	**23.13 - 44.91**
X-Large	**100 +**	**45.36 +**

Figure 13. In this figure, a key is shown depicting the weights for each weight class/group.

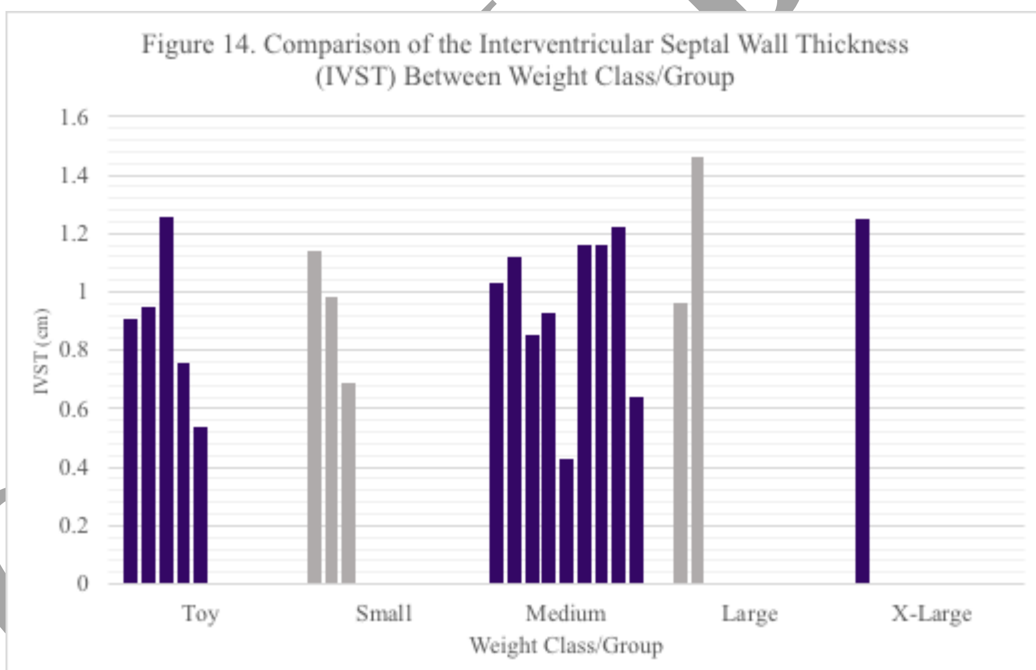

Figure 14. In this figure, a clustered column chart is used to display and compare the interventricular septal wall thickness for all 20 patients involved in the cardiac study, divided into their weight class/group. Instances of variation were noted possibly due to significant differences in age, as well as disease.

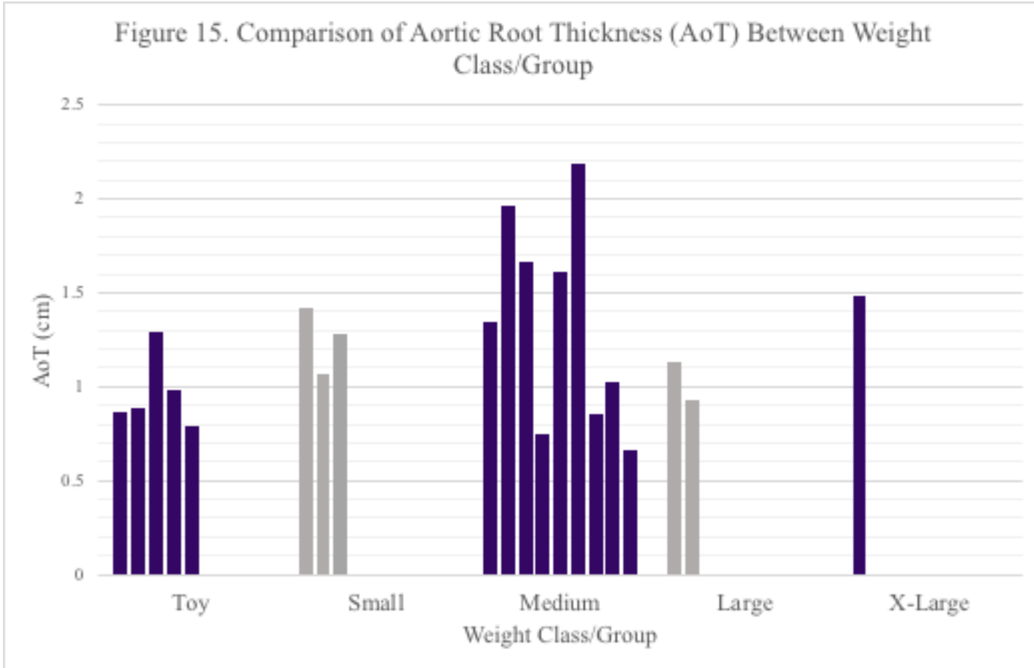

Figure 15. In this figure, a clustered column chart is used to display and compare the aortic root thickness for all 20 patients involved in the cardiac study, divided into their weight class/group. Instances of variation were noted possibly due to significant differences in age, as well as disease.

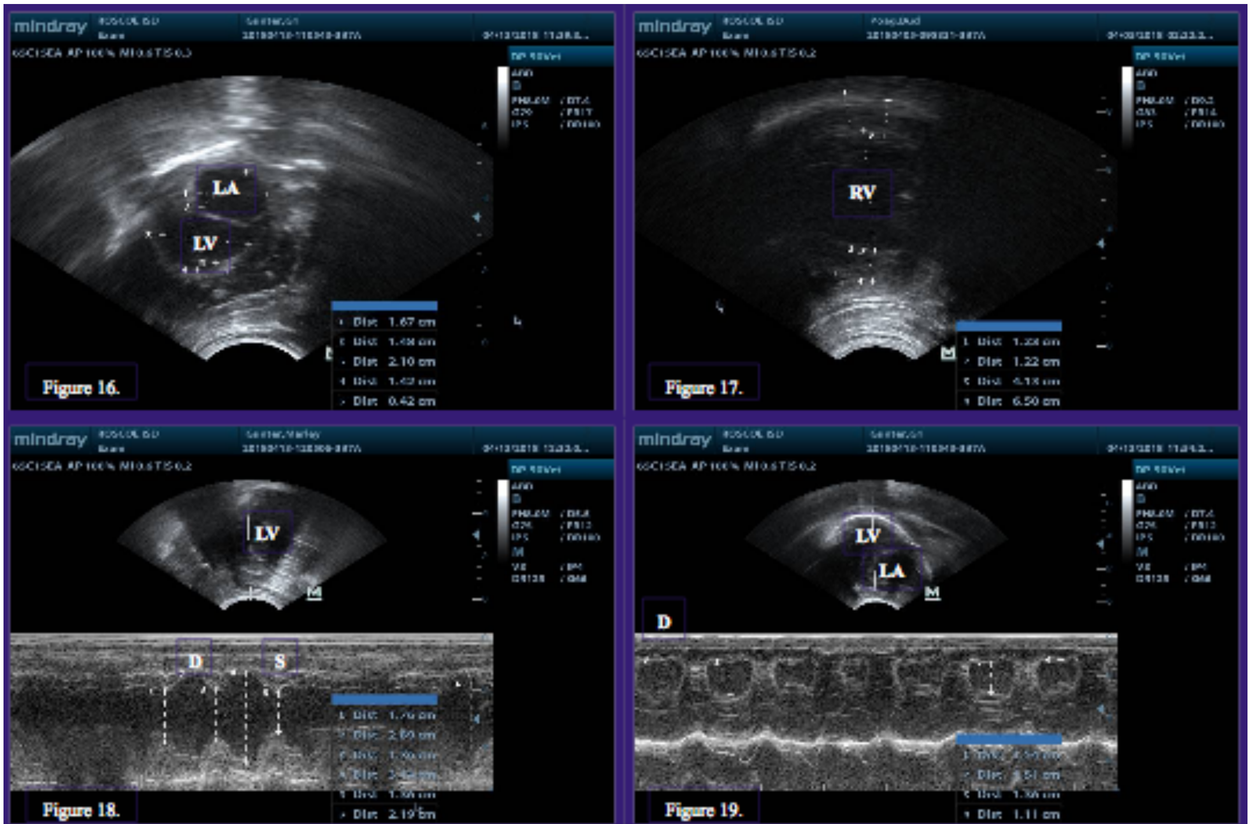

Figure 16. In this figure, the left ventricle, left atrium, and left ventricular posterior free wall are clearly visible using two-dimensional echocardiography from the right sided parasternal long axis view at the level of the mitral valve. **Figure 17**. In this figure, the right ventricle, tricuspid valve, and right ventricular free wall are clearly visible using two-dimensional echocardiography from the right sided parasternal short axis view at the level of the chordae tendineae. **Figure 18**. In this figure, the cardiac cycle (diastolic and systolic movements) of the left ventricle is displayed using motion-view echocardiography from the right sided parasternal long axis view at the level of the left ventricle. **Figure 19.** In this figure, the cardiac cycle (diastolic and systolic movements) of the left ventricle and left atrium is displayed using motion-view echocardiography from the right sided parasternal long axis view at the left ventricle and aorta.

DISCUSSION AND CONCLUSION

If canine gender is related to the size of cardiac structures; then, more active male canine breeds should have larger internal cardiac structures than females. After reviewing the data it was concluded that the hypothesis was proven correct. The researcher was unable to find any similar research investigating the correlation between gender, breed, and the size of internal cardiac structures; making this research project even more significant. Despite this research study being conducted in a manner to minimize the possibility of collecting inaccurate data, there are certain variables that were unable to be controlled. For instance, some canines participating in the cardiac study had a thick chest wall which made it more difficult for the sound waves to pass through and show a clear image. To counteract this, the frequency of the sound waves produced from the ultrasound was increased to make the images clearer.

During the examination, especially in larger canines, each inspiration was so large that the views of the cardiac structures were unable to be seen due to the lung tissue occluding the heart. The images were only obtained during the small window of expiration. Also, rapid changes in intrathoracic pressure, common during panting, made it difficult to obtain clear images of the cardiac structures. Changes in intrathoracic pressure cause artifacts which appear as abnormalities on the screen. Finally, the ribs and lung tissue made it difficult sometimes to obtain images in larger and smaller breeds of canines. To combat this, transducer position was changed to try and clear these structures out of the line of the sound waves.

Many constants were set to try and minimize variations. For example, sedation was not used on any of the animals because of the potential to interfere with the diastolic movement of the heart, as well as decrease the size of the ventricles. Also, the animal was always positioned in left lateral recumbency, with the legs extended cranially and caudally to maximize the size of the chest window. As previously mentioned, a protocol was established to ensure that the views and measurements collected were the same for each patient. The same ultrasonographer was used in every case to prevent variations in ultrasonography technique.

Since half of the patients in the study were on preventative medications, the researcher investigated the effects of the following medications on the heart: Heartgard™, Tri-Heart Plus™, Simparica™, Frontline™, and Bravecto™. After much research and conversations with different veterinarians, it was determined that these preventative medications had no major impacts on heart structures; subsequently, it would not skew any data.

Once the ultrasound images were displayed in real time, it became clear that some of the older dogs had calcifications and vegetations growing on the leaflets of the valves. Also, it was discovered during the procedure that two of the older dogs were suffering from hypertrophic cardiomyopathy, meaning that the outflow tract from the left ventricle is being restricted due to disease found in the cardiac muscle (Bussadori et al., 2000). This can cause insufficient blood flow to the systemic circuit of the animal's body. Also, one of the dogs was suffering from a form of Lyme disease that caused changes to the heart structure for that particular dog. Despite the disease being cured, the damage caused by the disease had already been done. Finally, two of the canines that participated in this survey tested positive for Dirofilaria immitis (heartworms). One had previously had the disease, while the other had an active case. Dirofilaria immitis can directly impact cardiac tissue, particularly tissue in the left and right ventricles which gives an inaccurate measurement.

If this project were to be replicated, there are a few adjustments that should be made. For instance, in the survey, a few questions should be added to inquire whether or not any of the canines participating had any preexisting medical conditions that would interfere with the study. If so, they should not be used because the results could become skewed. Also, the maximum age for participating in the study should be set for a max of ten years. Any dog over the age of ten years has a significant chance of skewing the study because of the cardiac muscle thickening caused by aging, as well as valvular anomalies that could interfere with capturing a clear image.

ACKNOWLEDGEMENTS

I would like to thank the Roscoe Collegiate Board of Trustees, Administration, faculty, and support staff for giving me the opportunity to conduct this research project. I would like to give a special thanks to the Roscoe Collegiate Edu-Vet Pet Hospital, particularly Dr. Betsy Oesch, DVM and Kelley Poag, CVA for their continuous assistance throughout the research process. I would like to sincerely thank Mrs. Shelley Gunter and Mrs. Kalyn Tate for their unwavering commitment to seeing their students succeed in all that they do.

REFERENCES

Abduch, M.C.D., Assad, R.S., Mathias Jr., W., & Aiello, V.D. (2013). The echocardiography in the cardiovascular laboratory: A guide to research with animals. *Arquivos Brasileiros de Cardiologia, 102*(1), 97-103. doi/10.5935/abc.20130239

Beard, D. (n.d.). Practical echocardiography: ECHOES in the "REAL WORLD." Retrieved from: http://www.delawarevalleyacademyvm.org/pdfs/oct06/PracticalEchocardiographynotes.pdf

Bussadori, C., Amberger, C., Le Bobinnec, G., & Lombard, C.W. (2000). Guidelines for the echocardiographic studies of suspected subaortic and pulmonic stenosis. *Journal of Veterinary Cardiology, 2*(2), 15-22.

Crippa, L., Ferro, E., Melloni, E., Brambilla, P., & Cavalletti, E. (1992). Echocardiographic parameters and indices in the normal Beagle dog. *Laboratory Animals, 26*, 190-195.

Estrada, A. (2017). *Echocardiography in general practice: 4 views to master*. Gainesville, FL: University of Florida. Retrieved from https://www.cliniciansbrief.com/article/echocardiography-general-practice-4-views-master

Ferasin, L. (2014, September). Introduction to echocardiography in small animal practice. *Itinerario di Cardiologia del cane e del gatto*, (1-43). [Milan, Italy]; Unione Italiana Società Veterinarie.

Gugjoo, M.B., Hoque, M., Saxena, A.C., Shamsuz Zama, M.M., & Dey, S. (2014). Reference values of M-mode echocardiographic parameters and indices in conscious Labrador

Retriever dogs. *Iranian Journal of Veterinary Research, 15*(4),341-346.

Hall, D.J., Cornell, C.C., Crawford, S., & Brown, D.J. (2008). Meta-analysis of normal canine echocardiographic dimensional data using ratio indices. *Journal of Veterinary Cardiology, 10*, 11-23. Retrieved from https://pdfs.semanticscholar.org/b0fd/9cb5117f8704f6f609e18c7a2e591a168324.pdf

IDEXX Laboratories. (2011). *Checklist of cardiac ultrasound images to obtain*. Retrieved from http://www.vetmedstat.com/Reports/CardiologyExaminationProtocols.pdf

Marieb, E.N., & Hoehn, K. (2016). *Human Anatomy and Physiology*. Essex, England: Pearson Education Limited.

Rishniw, M. & Erb, H.N. (2000). Evaluation of four 2-dimensional echocardiographic methods of assessing left atrial size in dogs. *Journal of Internal Veterinary Medicine, 14*, 429-435.

Singh, P., Singh, N., Mahajan, S.K., Singh, T. (2014). *Echocardiography as an approach for canine cardiac disease diagnosis*, Veterinary World 7(11): 960-965.